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Justification of the Design of the Two-shaft Mixer of Forages

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Abstract

Justification of the use of mixers in the processing of mixtures' feed is given in the article. Some designs of mixers are considered, research of some authors are noted. Existing shortcomings of the mixing process and designs of mixers are revealed. The sound design of a double-shaft mixer with a horizontal shaft and rectangular buildings are given in the article on the basis of a priori review. The experimental feed mixer is designed and manufactured on the basis of objectives and research hypotheses, a description which allows us to understand the essence of the work. In addition, the article reflects the theoretical calculation of the lobed mixer, the technique of the experiments. The experimental results are shown in graphs with the construction of corresponding values, tables, equations. General conclusions reported in this article show the finished work confirming the hypothesis of the research and execution of tasks.

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Keywords: preparation of forages; feed mixture; horizontal two-shaft mixer; rectangular case; power consumption

1. Introduction

Feed mixtures occupy a special place in animal husbandry. The feed mixture is allowed to implement the tasks of production products. Academics and practitioners from around the world demonstrated the advantage of feeding animals with feed mixtures [1].

The flow-process lines reduce the time for preparation of feed; reduce operating costs for preparation of feed mixtures at the present time. A number of significant drawbacks exist in this case. This applies to a large non-uniformity resulting feed mixture, which affects the growth rate of animal weight.

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Scientific research in the field of preparation of feed mixtures in mixers is given in the works of a number of leading scientists: Yu.I. Makarov, N. B. Uryev, V. V. Ovchinnikov, Z. Shterbaychek, G. M. Kukta, A.P. Ivanova, E.A. Raskatova, P. M. Zaiki, M. A. Taleysnik, I.A. Ulanov, F. Strenk, E.M. Klychev, A.G. Kasatkin, S. V. Evseenkov and others [2,3].

The criterion of assessing the quality of the mixture acts as an indicator of mixing granular mixture, which allows you to compare the theory with the perfect mix achieved. This is seen in the works of Y. Makarov, A.M. Melnikov, G.M. Kukta, A.I.Golosov, V.A. Korotkevich and others [4].

The way of creating new constructive solutions mixing machines is possible by reducing their energy intensity, energy costs for the production of the feed mixture.

Energy-saving technologies and providing the population with sufficient high-quality livestock products are one of the most urgent problems of modern agricultural production and it is connected with the creation of a strong food base. Rational use of energy in the preparation of feed mixtures is urgent.

2. Common part

The purpose of the research was to improve the effectiveness of the preparation of the feed mixture by the design of the mixer periodic action with a fixed rectangular housing and two horizontal blade working bodies. These researches were carried out in Kostanay State University named after A. Baitursynov of the Republic of Kazakhstan [5].

The main objectives of the research: to identify factors affecting the efficiency of the mixing process the feed mixture on the basis of the analysis of the research; to justify the design parameters of the mixer in the production of mixtures theoretically and experimentally. To develop a method of reducing power consumption of the mixer and to improve the design; to give an economic evaluation of the effectiveness of the pilot mixer.

We have put forward the hypothesis of the research is reducing the energy intensity of the mixing process under the joint influence of the design of the hull (the inner corners of the mixer are performed at angle "α" greater than the angle of friction of the feed material in steel is $ 22...31° for different feeds) and diameters of the screw (one screw has a smaller diameter and pitch of the blade) [6].

A paddle mixer can be applied when working with granular and viscous materials. This is due to the possibility of changing the angle of rotation of the blade about the axis of rotation of the shaft, the bevel angle of the inner surface of the housing of the mixer, the pitch of the blade.

The lack of a paddle mixer in the high cost of energy consumed for the movement of material can be eliminated by changing the above parameters of the mixing process, including a change in the internal corners of the mixer.

Thus, the intensity paddle mixer will depend on the design parameters of the mixer, physical and mechanical properties of mixed material, the load factor of the mixer, the friction material, the coefficient of performance (cp) of the drive [7-9].

Structural and technological features of this mixer must be considered to determine the cost of power mixer in a computational model of the process. The layout of the blades is the main structural feature (figure 1).

The blades of the same type installed in the mixer on both shafts. The blades arranged on the shafts opposite to each other at an angle of 30 degrees, in a direction to mix the material. Counter flows of mixture within the zones of each shaft are eliminated in this traffic and have been intensifying in the process form a homogeneous mixture, which is described by an exponential function of the process indicator of the degree of separation of the mixture.

Therefore, the vast number of blades of both shafts is in the same terms, as the degree of loading, and homogeneity of the working environment. This feature of the mixing process allows us to consider the work of one of the blade equal for all blades. When this mixture is able to perceive the external load (shear resistance), as well as to be condensed as a result of an irreversible process is a relative redistribution of particles in a multiphase environment, which is manifested in a limited area of the mixer is in range of the blade.

As a result, the area of excitation of the mixture formed in front of the blade, inside which there is a transfer of the pressure blades from particle to particle and their redistribution. This leads to some compaction of the mixture within the zone of excitation. In addition, a floating volume of the mixture is limited to the cylindrical shape of the bottom of the mixer and the surface of the blade located under the angle to the shaft axis.

If the blade of the mixer is to consider the resultant «*R*» of all the resistors acts on the blade (figure 2), deviates from the normal to the angle «*φ*» of friction. The normal component «*P*» of this effort lay in the direction, circumferential and axial. The result is the force of «P_p», that tells the particle rotational motion, and «P_o»**,** that move these particles in the axial direction [10,11].

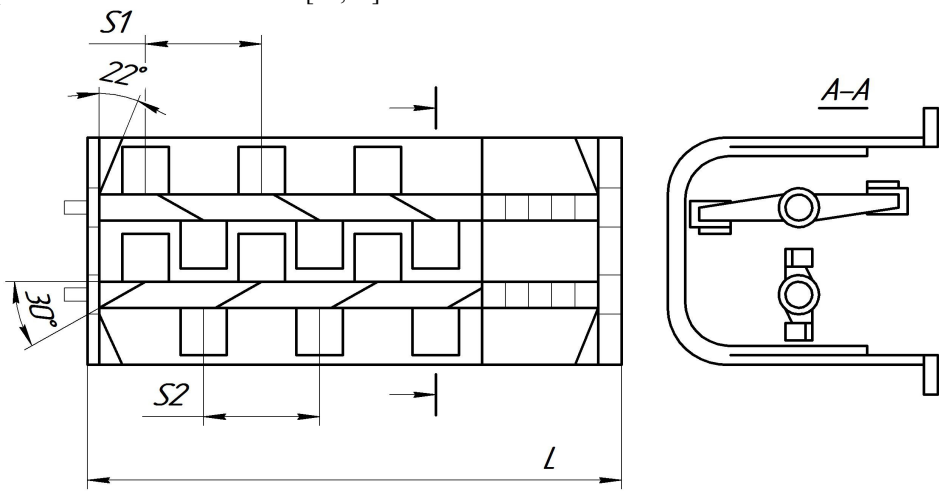

Fig. 1. Schematic diagram of the location of the paddles in the mixer

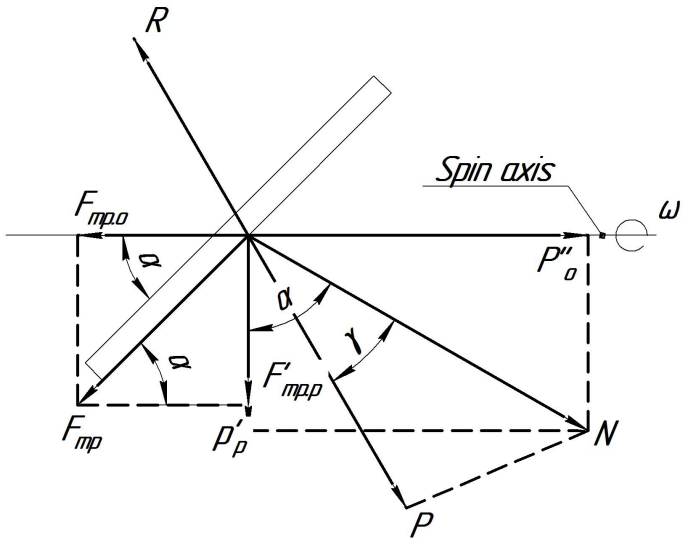

Fig. 2. The forces acting on the blade of the mixer

The optimal angle of installation of the paddle considered from 30 to 60 degrees depending on the physical and mechanical properties of the material from literary sources.

Stagnant zone is formed at small angles of rotation of the paddle (α=7...10 degrees) ahead of the blade leading to increase in power and reduction of homogeneity. It is almost absent when you increase the angle (α=60 degrees), but the mixing time of the mixture components is increased [12].

The angle of rotation of the blade will be 30 degrees, the pitch of the blades of one of the shafts will be 0.55 m, the other of 0.48 m. In addition, the slant inner surface of the housing of the mixer used in the designed structure,

which will be from 22 to 31 degrees, which corresponds to the angle of friction of the feed material for steel. This design allows it to reduce the energy intensity of the mixing process.

Selection and justification of composition of feed mixtures was carried out by the methodology of experimental studies, the mixing process is studied, the method of determining physico-mechanical and rheological properties of the feed mixture is offered. In the process of mixing dry and wet food, place in a paddle mixer will affect the complex design and technology, operating and kinematic, physical and mechanical and rheological parameters [13-15].

The experimental part of the work included the following definitions: the dependence of the intensity of the mixer from the diameters of the circles described by the blades; the dependence of the intensity of the mixer from the housing construction; the composition of the feed mixture, and its physical and mechanical and rheological properties; friction feed on steel; quality mixing.

We created the installation for experimental verification of the working hypothesis on the possibility of reducing the energy intensity of feed mixer having two shafts with rectangular blades and the casing (fig. 3).

The slot "3" is performed to replace the shafts in end plane of the housing at which the shaft can be removed and moved (fig. 4).

Fig. 3. Experimental set up

The point of their fastening by the threaded holes "4" is provided when conducting research with the replacement shafts. Changing the modes of operation of the mixer is carried out by shifting the flat belts on the drive. The blended material was unloaded after the stopping of the mixer through the roof 1 is fixed to the case 2.

The whole process was monitored using several devices. These are some instrument of the determine the frequency of shaft rotation (tachometer A 2236), current and voltage (M 2018).

The quality of the mixture was determined by the developed technique, instrument of determining bulk density, particle size distribution composition, humidity of the mixture [16,17].

The mixture consisted of: corn, bran, flour, salt.

In addition, methods for determining the physical and mechanical and rheological properties of mixtures were developed, including definitions of bulk density, determination of moisture content of mixtures, determination of angle of repose and particle size distribution of mixtures, determine the coefficient of friction of the feed mixture; determine the quality of the feed mixture.

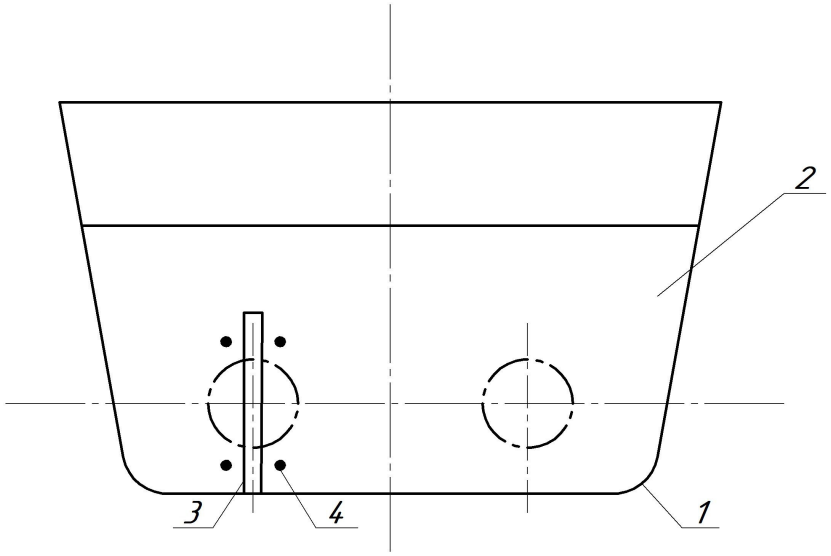

Fig. 4. Arrangement of shafts: 1-the unloading hatch, 2-the housing of mixer 3-slot, 4-point mounting shaft

The results of research of process of mixing feed when feeding pigs - boars were obtained. The values of the intensity of the mixing process of the new design of the mixer show a decline of 15 % in comparison with the old design (with a rectangular case). The values of factors - speed of shaft rotation and time of mixing of the feed are identified based on the conducted research. But when you install a shaft with smaller diameter blades, the mixing time increased, the cost of energy did not subside. Therefore, according to the above technique are performed optimization experiments with factor - angle of bevel of the inner surface of the housing.

Table 1. Encoding factors of the optimization experiment.

Factor	Id (code)	variability interval	Level of factors		
			lower -1	main 0	upper +1
Inner bevel angle, *j,* degrees	X_1	10	10	20	30
Moisture forage mixture, %	X_2	25	15	40	65

The parameters entering into structure of mathematical model were determined. The made experiments allowed optimizing key parameters of process of mixing that gave the chance to receive the set uniformity degree at the minimum energy consumption (table 1).

As a result of experiments the conclusion was drawn that the most significant regulator of parameters of process of mixing is degree of uniformity of mix. Definition of optimum parametrical area of process of mixing in bladed mixers is result of researches. In each output parameter, proceeding from technological conditions restrictions were introduced: on power consumption E < 4,6 kJ/kg; on uniformity degree $\Theta > 90\%$. As power consumption is expressed through productivity and power, it is necessary to introduce restrictions: on power - N < 0,6 kW; on productivity - Q = 135 kg/min. Graphic dependences of influence of parameters of process of mixing for the weekend qualitative and power indicators are constructed [18,19].

Adequacy of the received dependences is checked by Fischer's criterion defined for uniformity degree Θ [20,21]. At the accepted significance value α=0,01, Fischer's criterion of F=1,94, the equation is significant. Disp=694,5903, S=26,35508. By the received results the conclusion was drawn that the model adequately describes process of mixing in bladed mixers. The analysis of the obtained data shows, the best indicator of mixing is reached at an angle closer to 20-30 degrees. The bulk density of material in a loose state $\rho_н$, kg/cm3, calculated with an accuracy of 0,01 g/cm3 as an arithmetic average on a formula:

$$\rho_H = \frac{(m_1 - m_2)}{V} \quad (1)$$

where m_1 - the mass of the cylinder with material; m_2 - the mass of the cylinder without material; V - volume of the cylinder.

Volume for mixing was counted taking into account a formula 2. Moisture of forage was calculated as a percentage on a formula:

$$W = 20(m_1 - m_2) \quad (2)$$

Parallel to the above-mentioned humidity measurements we are used the device such as "Farmpoint". Proceeding from B. V. Kononov and A.K. Sviridenko's researches coefficient of friction of the movement of compound feeds on steel - 0,37 [22].

At determination of coefficient of friction in experiences were taken a little different in moisture feed mixture (W= 3...65%).

Results on determination of quality of a feed mixture in mixers with various angles of the body are received, it should be noted that: uniformity of a feed mixture in the mixer with the rectangular body is reached at moisture of 65% that is noted by experimental values θ =0,90; uniformity of a feed mixture in the mixer with an internal angle of the body equal 22 degrees is reached at moisture of 65% that is noted by experimental values θ=0,988; comparison of the received experimental values allows to bring result that production of the case of the mixer with an inner angle to 22 degrees raises degree of uniformity of a feed mixture.

The received average values of power consumption of process of mixing show its decrease by 15%.

Results of comparison of theoretical and experimental research of process of mixing of a feed mixture show that the divergence will make about 11,5% (fig. 5).

Confirmation of results of researches of process of mixing of forages is obviously. Nature of course of process is confirmed. As the main results of researches were directed on check and confirmation of a working hypothesis, about possibility of decrease in power consumption of process of mixing due to change of inner angels of the body of the mixer, the received results are built in the form of the schedule (fig. 6).

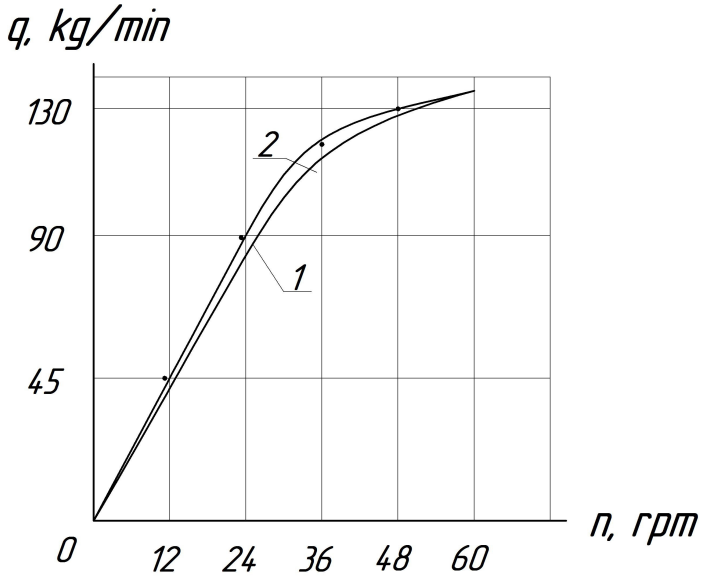

Fig. 5. Dependence of productivity on the frequency of rotation of shaft of the mixer: 1-theoretical curve; 2-experimental curve

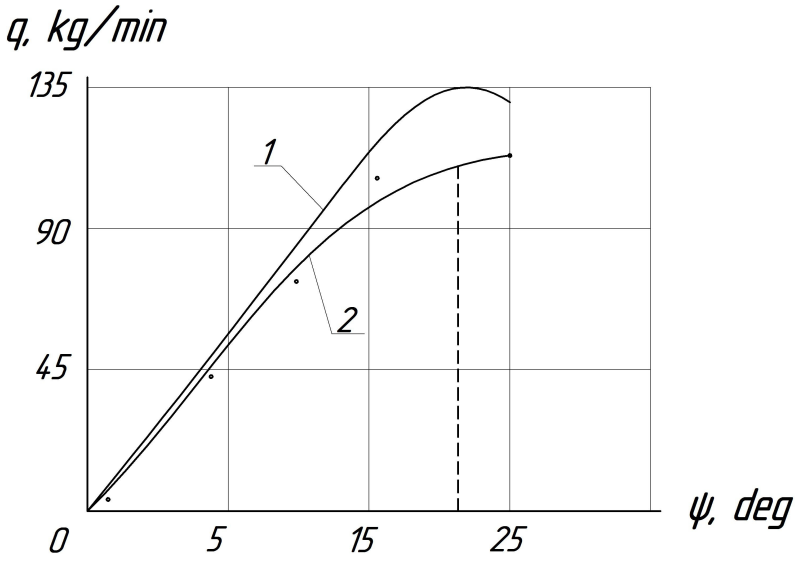

Fig. 6. Dependence of productivity on an angle bevel of an inner surface of the body of the mixer: 1-theoretical curve; 2-experimental curve

3. Conclusion

1. Particle size distribution has a great influence on the digestibility of feed by animals. In turn the cars used to receiving feed mixes can't provide fully the demanded size of particles and have a number of essential shortcomings, such as the low productivity, a long cycle of preparation, high metal consumption of constructions, big power consumption of process. All this does preparation process very difficult and labor-consuming.

2. As a result of experimental studies have been conducted simulation of a mixer with a rectangular body, which showed that at the time of the mixing process is observed: increasing accumulation of feed material in the mixing angles; increases mixing time of materials; decreases the degree of homogeneity of the feed mixture; increases the energy consumption of the process.

3. In analysing the results of experiments with three the different constructions of blade shaft mixers is revealed the most effective construction (blades with a circumference of 250 mm and 210 mm). With this construction, there are the best characteristics of the mixing process, contributing to a reduction in energy intensity.

4. Constructive scheme of paddle mixer is substantiated; it reduces the energy intensity of the process of preparation of feed mixtures by installing additional inserts in the angles of the mixer body.

5. Optimum values of frequency of rotation of working bodies of the mixer - 60 rpm limited to a limit, the mixing time noted by the top limit of 540 seconds are established.

6. It is experimentally established that: production of the body of the mixer with an inner angle to 22 degrees raises degree of uniformity of a feed mixture; load of the electric motor depends on the sizes of blades and their step; the design of blades, provides uniform mixing of components (it allows to receive the weight, uniform in the structure, which particle size distribution conforms to zoo technical requirements).

7. The laboratory sample of the mixer which passed tests in the conditions of chair of cars, tractors and cars, engineering faculty, KSU named after A. Baitursynov is developed and made. In the course of test it is established that the electric power expense on 15% decreased, the consumption of grain mix was decreased twice per day.

8. According to the developed design of the mixer was obtained innovative patent of the Republic of Kazakhstan "Feed mixer", registered in the Register of expertise department of Astana city on 08.05.2012 №27011 (the authors are Gavrilov N.V. and Zhanabayev J.A).

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